Lecture by Prof. Kirchhoff: "On the Solar Spectrum," on Oct. 28, 1859.

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A ray of light is known to undergo a sudden change of direction, a "refraction" when it passes from one transparent medium to another. The consequence of this is that a ray of light falling on a glass prism leaves it in a direction very different from that in which it hit the prism. It is equally well-known that the light of the sun, and of almost all earthly light-sources, consists of various parts, which differ from one another in their colour by the extent to which they are refracted. The constituents of a sunbeam are separated from each other by passing it through a prism; they then exit in different directions. If one looks through a prism for a point-like opening and an opaque screen, through which sunlight penetrates, one sees a long line of light instead of the point of light, which is horizontal when the prism is vertical, red at one end, at the other is violet coloured and shows all colour transitions from red to yellow, green, blue to violet. The appearance becomes more beautiful when you look through the vertically placed prism for a vertical slit through which sunlight falls; then one sees a horizontal band, which is broad, as the crevice is long, and shows in the different parts of its length the different colours mentioned. This strip is called a solar spectrum. If the prism is good and the gap narrow, one sees in the spectrum several dark lines that run vertically, in the sense of the width of the spectrum. If one introduces a telescope between the eye and the prism and thus enlarges the spectrum, one sees an innumerable quantity of such dark lines, which appear partly individually, partly in groups, and show all degrees of fineness. The parts of the spectrum, apart from their brilliant colours, are given such a variety, that a pure solar spectrum is a phenomenon which, like the appearance of the starry sky, always retains its charm, however often one has perceived it. With the same regularity with which the stars appear on the sky sphere, these dark lines also appear in the solar spectrum. This remarkable fact, the existence and constancy of these dark lines, has been discovered by the famous Munich optician, Fraunhofer, and the lines are therefore called the Fraunhofer lines. As far as their explanation is concerned, so much is plainly clear that they must have their reason in the fact that in the light which we receive from the sun, constituents of certain refrangibility and colour are absent or at least much weaker than the neighbouring ones. The corresponding to these constituents. The parts of the spectrum corresponding to these constituents appear dark. Either the sun emits comparatively little of these constituents, or they are more strongly absorbed in our atmosphere by absorption than the others. It can be shown that the one and the other case takes place. Certain of the Fraunhofer lines are the clearer the closer the sun is to its sunrise or sunset, the farther the way is, the sun's rays to travel in our atmosphere. These lines will come from our atmosphere. Others always show the same strength, which is also the position of the sun in the sky; on these lines our atmosphere can have no part; they have their reason in the sun. Among the latter are the most distinct ones of the Fraunhofer lines, among others also those which Fraunhofer has designated by the letters A, B,..., And which have a most important significance for practical optics. Without the dark lines of the spiritual spectrum, one would not be able to make the quality of the telescope and microscopes that we have today; Fraunhofer's lines A, B, C,... are used to measure the refractive ratios of the glasses corresponding to certain parts of the spectrum from which the lenses for an optical instrument are to be ground, and after these measurements the curvatures are calculated must be given to the lens surfaces, so you get clear and colour-free images. Apart from the practical importance that the Fraunhofer Lines possess, they are probably to be accorded a higher scientific degree. They are for the most part, as mentioned, conditioned by the sun, and indeed by their materiality; they therefore offer a possibility, and probably the only one, to draw conclusions about the material nature of the sun. Such conclusions are based on an observation that I made and which led me to these disputes. Before I can describe it, I have to make some more sense about the spectra. Send light sources ahead. The spectrum of a candle flame shows no trace of dark lines; in it the brightness changes only gradually, increasing from the red end to the yellow and from here to the violet or blue, without cracks

appearing in the brightness. Certain salts, which are brought into the flame, especially chlorine-metals, show here and there on the light ground even brighter lines, which soon appear less sharply delimited. In this regard, the salt is especially excellent. The smallest amount of it, which is brought into the flame, causes two perfectly sharp light lines to appear very close to each other, which are exactly at the places of the spectrum at which Solar spectrum two dark lines are present, which are designated by the Fraunhofer with the letter D. The small amount of common salt usually found in a candle is often sufficient to show these bright lines; Fraunhofer has already found them in the spectrum of a candle flame and has demonstrated their exact coincidence with the dark double line D of the solar spectrum. But they are much more pronounced when one purposely brings some salt into the flame of the candle, or even into the hotter flame of Bunsen's lamp. By the way, sodium causes the streaks, for other sodium salts produce the same effect as soon as they are only volatile in the flame. The exact agreement of these sodium strips, as I shall call them, with the dark lines D of the solar spectrum, is certainly a most striking fact; she becomes even more striking in that she does not stand without analogy; in fact, Brewster has found that the spectrum of the flame obtained when burning saltpetre on coals contains bright sharply delineated lines which coincide exactly with other dark lines of the solar spectrum, namely those of Fraunhofer designated by A, a, B.

Such a correspondence of dark lines of the solar spectrum with bright spectra of coloured flames can not be accidental; but until now one could not find a reason for it and, therefore, could not draw conclusions from it. This gap is filled by my observation.

Together with Bunsen, I investigated the spectra of coloured flames, the exact knowledge of which promises considerable benefits for qualitative chemical analysis. We wanted to compare these spectra directly with the solar spectrum, and so we hit the device that at the same time sunlight and the light of a flame fell through the gap on the prism. The sun's rays had to pass through the flame before they reached the gap. We first used a salt flame. We had dampened the sunlight, so that the weaker light of the salt flame could be perceived by it. At the place of the dark lines D, the two bright sodium stripes appeared. We then intensified the sunlight to find the limits to which it was still possible to perceive the sodium streaks. When the intensity of the sunlight had exceeded a certain value, to my astonishment I perceived the dark double line D in quite unusual strength. The flame was alternately removed and brought back into the path of the sun's rays; this experiment undoubtedly showed that the lines D became darker when the sunlight was allowed to pass through the saline float. It had to be very strange for the first moment. It can only be understood if one accepts;

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Given this, it is clear that if the sunlight is sufficiently intense, the light corresponding to the dark lines D can be weakened by the common salt flame more than the cooking flame itself, that is, in the presence of the latter, the lines D darker, ie may appear more distinct than without it.

It was to be expected that in the case of an artificial light source of sufficient intensity, in whose spectrum the dark double line D does not occur, it would be possible to cause the light to pass

through a saline flame. An attempt made with Drummond's light has fully met that. By an alcohol flame, was brought into the common salt, succeeded in the spectrum of Drummond's light, the dark double lens D in the fineness and sharpness, as it happens in the solar spectrum to produce.

It is almost certain that a phenomenon so sharply defined as the appearance of two dark lines at particular places in the spectrum must always be traced back to the same cause; it is therefore almost certain that the dark double line D in the solar spectrum, as in the experiments just described by sodium must be caused. We have to look for this sodium in the solar atmosphere, because the Earth's atmosphere can not derive the line D, because in the solar spectrum it always shows to the same degree as the state of the sun, and because it is in the spectra of some fixed stars is missing while she is noticed in those of others. We are therefore led, with necessity, to the conclusion that sodium is in the glowing solar atmosphere.

The peculiarity of the flame of sodium from the rays of light which pass through it, and to weaken those whose refractability is the same as that which it emits, must have a more general reason. It is reasonable to assume that all flames have this characteristic. I have been so happy to confirm this assumption by another observation. Together with Bunsen I discovered the interesting fact that in the spectrum of the lithium flame there is a very bright, completely sharply delimited red line, which in the middle lies between the Fraunhofer lines B and C. I let sunlight pass through a powerful lithium flame and saw, with increased intensity, that the bright lithium line was transformed into a dark one that had the very character of the Fraunhofer lines.

It can be said with much probability that any of the Fraunhofer lines that are not derived from our atmosphere have their cause in the presence of a certain chemical constituent in the solar atmosphere, that of the flame brought into the spectrum of that producing a bright line in the corresponding place.

It is the way to the qualitative chemical analysis of the solar atmosphere. One has to study the spectra of the different flames, and look for bright lines in them, which agree with dark ones in the solar spectrum. If one has found one, one has to conclude that the substance that produced the bright line in the spectrum of the flame occurs in the solar atmosphere. I already suggest that Brewster found in the spectrum of the saltpetre flame bright lines that agree with A, a, B; These bright lines are undoubtedly derived from potassium. So also potassium is in the solar atmosphere. According to a study to which I have subjected the spectrum of the iron flame, I also believe that I can assert the claim that iron is one of the same.